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MULTIMEDIA UNIVERSITY

FINAL EXAMINATION

TRIMESTER 3, 2021/2022

EMF2016 ELECTROMAGNETIC THEORY

(All Sections / Groups)

10 AUGUST 2022

9 A.M – 11 A.M.

(2 Hours)

INSTRUCTIONS TO STUDENTS

1. This question paper consists of 11 pages including this cover page with 4 questions only. Common constants for air are listed on Page 5. Equations are listed on Page 6.
2. Attempt all four questions. All questions carry equal marks and the distribution of marks for each question is given.
3. Please print all your answers in the answer booklet provided.
4. Please tie and submit worked Smith charts together with the answer booklet.

Question 1 (25 marks)

- (a) A 120Ω transmission line is terminated by an antenna with an impedance of $(50 + j65) \Omega$. If the distance between two consecutive maximum voltage points are 10 cm, calculate:
- (i) The wavelength. [1 mark]
 - (ii) The reflection coefficient at the load. [4 marks]
 - (iii) The standing wave ratio. [2 marks]
- (b) A $(70 - j120) \Omega$ antenna terminates a 50Ω lossless transmission line. Using a smith chart, determine:
- (i) The standing wave ratio. [4 marks]
 - (ii) The location of the nearest voltage maximum from the load. [3 marks]
 - (iii) The input impedance at the location 0.32λ from the load. [3 marks]
 - (iv) The input admittance at the location 0.32λ from the load. [2 marks]
 - (v) The nearest location from the load to insert a matching element. [6 marks]

Question 2 (25 marks)

- (a) A static conductor on the x-y plane with the sides of $4 \text{ cm} \times 7 \text{ cm}$ is shown in **Figure Q2(a)**. A magnetic field $\vec{B}$ is given by

$$\vec{B} = -\hat{z} 80y \cos \omega t \text{ (T)}.$$

Determine:

- (i) The induced electromotive force (emf) across a small gap created in the loop, if the angular frequency $\omega = 10^5 \text{ rad/s}$. [9 marks]
- (ii) The current and its direction, if the resistor connected across the gap is 3Ω . [4 marks]

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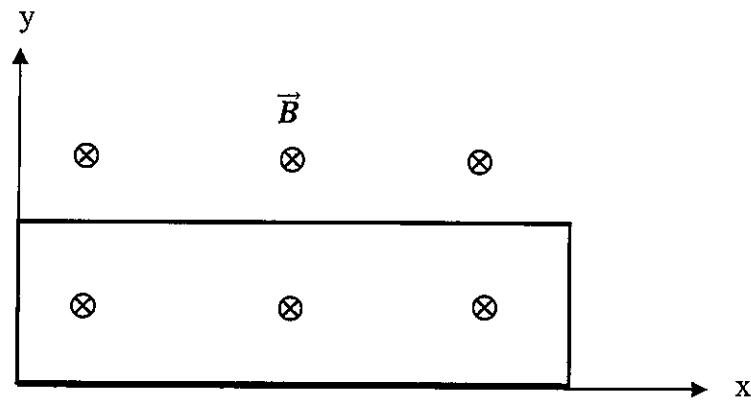


Figure Q2(a)

- (b) A conducting rod shown in **Figure Q2(b)** is moving at a constant velocity $u = \hat{z} 15 \text{ m/s}$. The current flow in the long straight wire is given by

$$I(t) = 10 \sin 10^4 t \text{ A},$$

- (i) Determine the induced emf in the rod. [8 marks]
- (ii) What is the maximum induced emf in the rod? [2 marks]
- (iii) At what time the emf will achieve the maximum value? [2 marks]

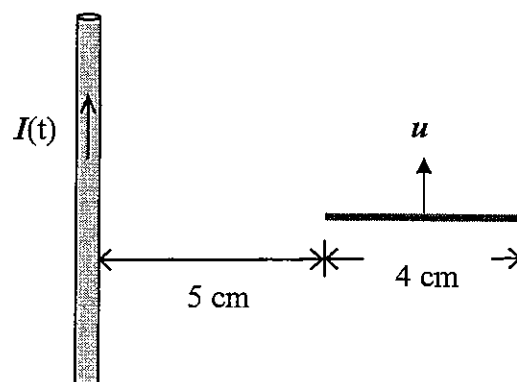


Figure Q2(b)

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Question 3 (25 marks)

(a) An electromagnetic wave is described by $\vec{E} = \hat{z} 20 \sin(8\pi \times 10^8 t - 6x)$ V/m. The wave propagates in a lossless non-magnetic material. Determine:

- (i) The direction of wave propagation. [1 mark]
- (ii) The period. [2 marks]
- (iii) The wavelength. [2 marks]
- (iv) The phase velocity. [2 marks]
- (v) The relative permittivity of the medium. [2 marks]
- (vi) The intrinsic impedance. [2 marks]

(b) A 50-MHz plane wave in air (medium 1) impinges at normal incidence on a flat surface of a lossless non-magnetic dielectric medium (medium 2) with relative permittivity $\epsilon_r = 42$. The electric field intensity of the incident plane wave in air is 60 V/m.

Determine the following:

- (i) The phase constant in air. [2 marks]
- (ii) The phase constant in the dielectric. [2 marks]
- (iii) The reflection coefficient. [5 marks]
- (iv) The average power densities of the incident and reflected waves. [5 marks]

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Question 4 (25 marks)

- (a) A $3 \text{ cm} \times 1 \text{ cm}$ air-filled waveguide is operating at 16 GHz. Determine:
- (i) All possible propagating modes and their cutoff frequencies. [6 marks]
 - (ii) The intrinsic impedance of the highest mode. [4 marks]
 - (iii) The group velocity of the lowest mode. [2 marks]
- (b) An air-filled rectangular waveguide has a cutoff frequency for TM_{11} and TE_{30} modes both equal to 10 GHz.
- (i) Determine the dimension of this waveguide. [4 marks]
 - (ii) At 8 GHz, justify whether the dominant mode will propagate in the waveguide. [3 marks]
- (c) A rectangular waveguide with dimensions $2.5 \text{ cm} \times 1 \text{ cm}$ is to operate at 12 GHz. The waveguide is filled with a medium characterized by conductivity $\sigma = 0$, and relative permeability $\mu_r = 1$, for TE_{10} mode and relative permittivity $\epsilon_r = 6 + (\text{last two digits of your ID} / 100)$, determine:
- (i) The cutoff frequency. [3 marks]
 - (ii) The phase constant. [3 marks]

Common constants for air

Speed of light, c	$= 3 \times 10^8 \text{ m/s}$
Permittivity, ϵ_0	$= 8.854 \times 10^{-12} \text{ F/m}$
Permeability, μ_0	$= 4\pi \times 10^{-7} \text{ H/m}$
Intrinsic impedance, η_0	$= 377 \Omega$

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Equations

$$\gamma = \sqrt{(R' + j\omega L')(G' + j\omega C')}$$

$$Z_0 = \sqrt{\frac{R' + j\omega L'}{G' + j\omega C'}}$$

$$Z_{in}(l) = Z_0 \frac{Z_L + jZ_0 \tan \beta l}{Z_0 + jZ_L \tan \beta l}$$

$$Z_{in}^{sc}(l) = jZ_0 \tan \beta l$$

$$Z_{in}^{oc}(l) = -jZ_0 \cot \beta l$$

$$Z_0 = \sqrt{Z_{in}^{sc} Z_{in}^{oc}}$$

$$Z_{in}\left(\frac{\lambda}{4}\right) = \frac{Z_0^2}{Z_L}$$

$$\tan(\beta l) = \sqrt{-\frac{Z_{in}^{sc}}{Z_{in}^{oc}}}$$

$$\Gamma_L = \frac{Z_L - Z_0}{Z_L + Z_0}$$

$$d_{max} = \frac{\theta_\Gamma \lambda}{4\pi} + \frac{n\lambda}{2}$$

$$SWR = \frac{1 + |\Gamma|}{1 - |\Gamma|}$$

$$\tilde{\mathbf{H}} = \left(\frac{1}{\eta}\right) \hat{\mathbf{k}} \times \tilde{\mathbf{E}}$$

$$\tilde{\mathbf{E}} = -\eta \hat{\mathbf{k}} \times \tilde{\mathbf{H}}$$

$$f_{c_{mn}} = \frac{u_{p0}}{2} \sqrt{\left(\frac{m}{a}\right)^2 + \left(\frac{n}{b}\right)^2}$$

$$\beta_{mn} = \beta_0 \sqrt{1 - \left(\frac{f_{c_{mn}}}{f}\right)^2}$$

$$u_p = \frac{u_{p0}}{\sqrt{1 - \left(\frac{f_{c_{mn}}}{f}\right)^2}}$$

$$u_g = u_{p0} \sqrt{1 - \left(\frac{f_{c_{mn}}}{f}\right)^2}$$

$$Z_{TM} = \eta \sqrt{1 - \left(\frac{f_{c_{mn}}}{f}\right)^2}$$

$$Z_{TE} = \frac{\eta}{\sqrt{1 - \left(\frac{f_{c_{mn}}}{f}\right)^2}}$$

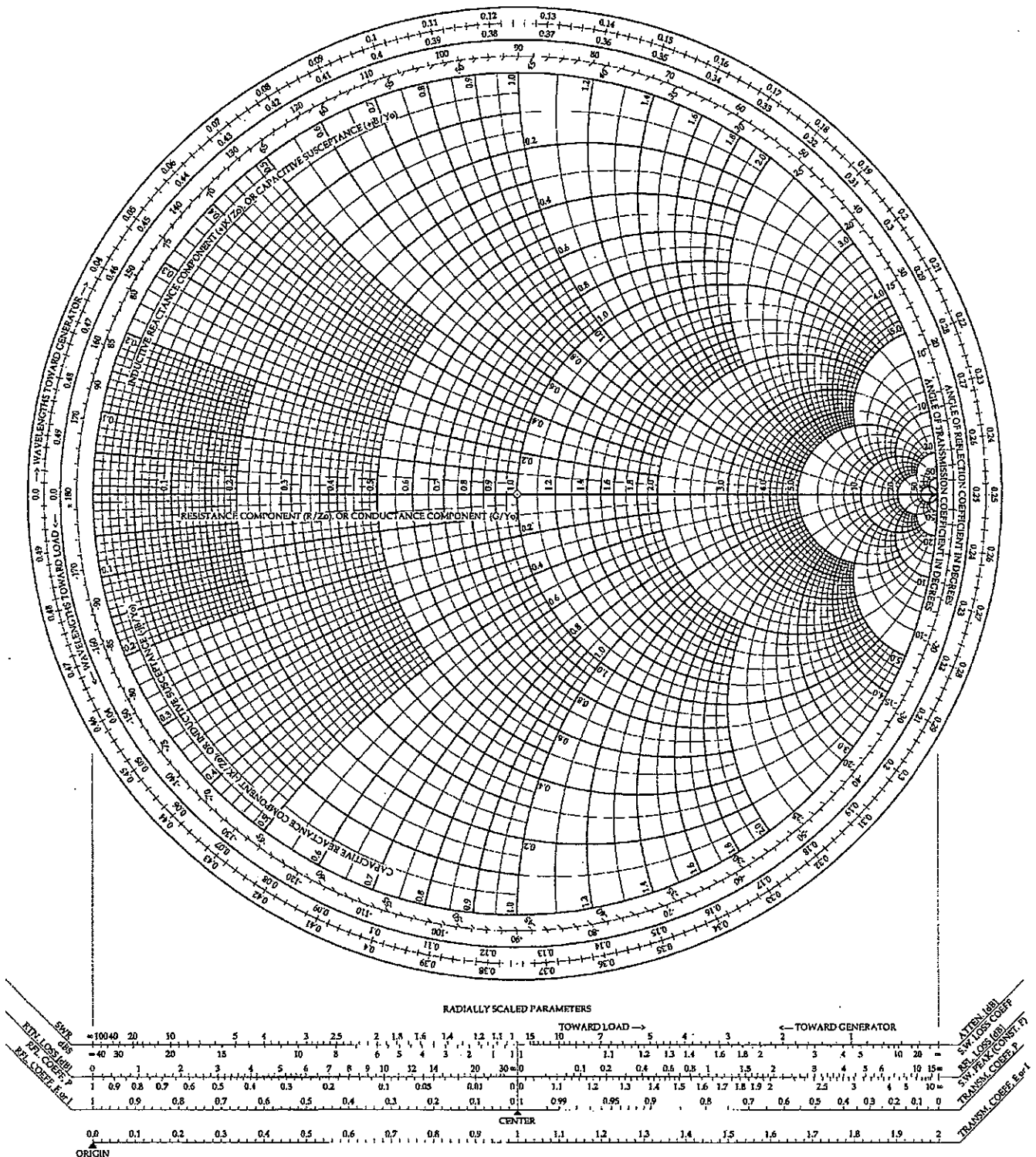
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The Complete Smith Chart

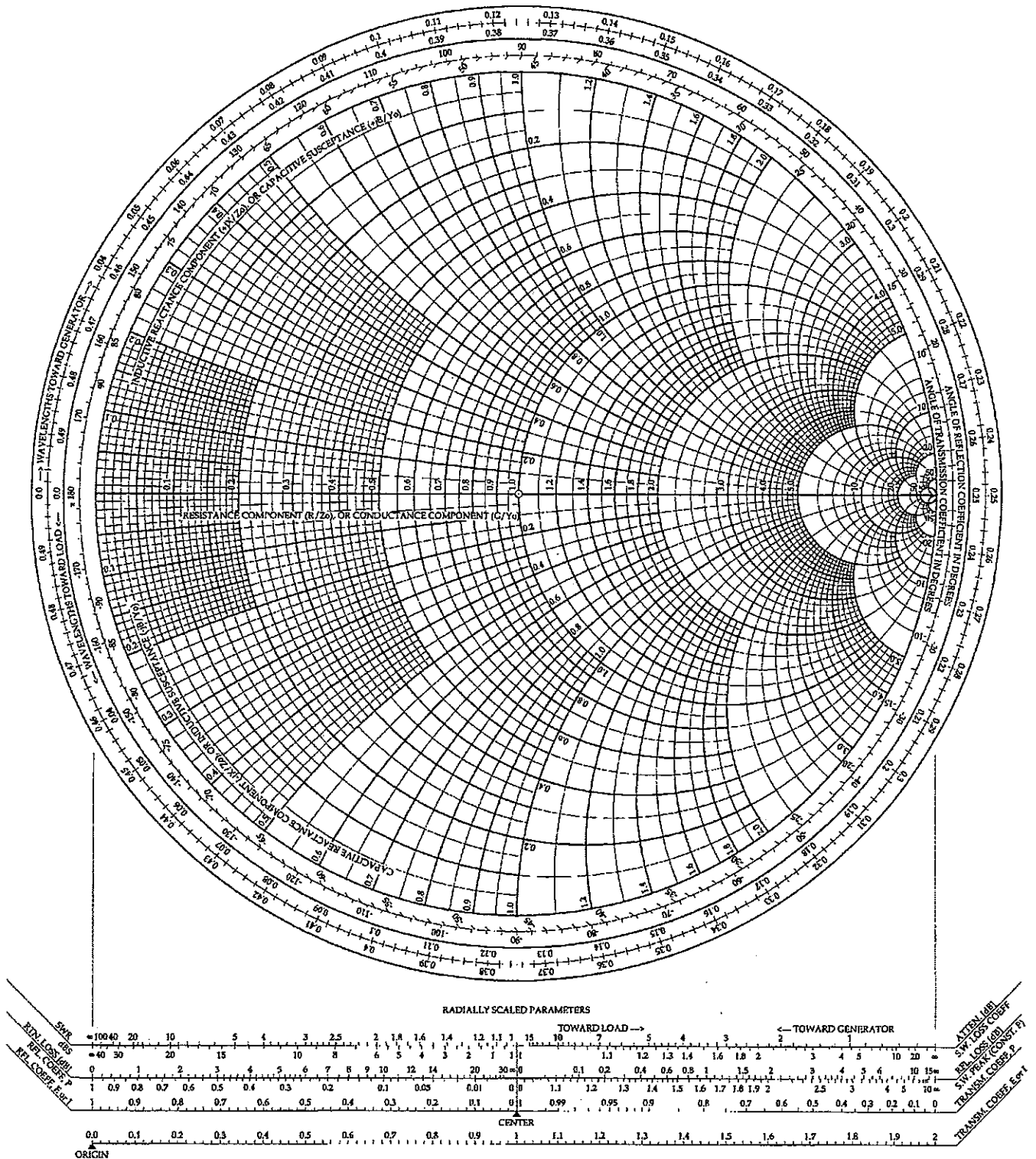
Black Magic Design



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The Complete Smith Chart

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